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SAFETY TEST ON AN/PRC-96 TRANSMITTER

BY (10) R. F. BIS D. L. WARBURTON C. F. FREEMAN (9) Final rept.

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Lithium Sulfur Dioxide batteries are used to power an emergency radio transmitter carried aboard naval submarines. These batteries can release undesirable gasses if venting occurs. A limited investigation was undertaken to determine the types and quantities of gasses released from these batteries to establish under what conditions the transmitter can be safely stored aboard submarines.

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SUMMARY

Lithium Sulfur Dioxide batteries are used to power an emergency radio transmitter carried aboard naval submarines. These batteries can release undesirable gasses if venting occurs. A limited investigation was undertaken to determine the types and quantities of gasses released from these batteries to establish under what conditions the transmitter can be safely stored aboard submarines.

J. R. Dixon

J. R. DIXON
By direction

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Chapter 1

INTRODUCTION

An emergency radio transmitter (AN/PRC-96) is used aboard naval submarines. The power for the transmitter is supplied by two "D" size Li/SO_2 cells. The use of lithium anode batteries was specified by the original equipment manufacture, since no other electrochemical system could provide adequate capacity to meet the transmitter specifications.

The AN/PRC-96 battery pack is composed of two "D" size cells connected in series with a three ampere fuze and secured together by hard wiring and heat shrink tubing. Each cell is hermetically sealed and has a safety pressure vent.

The three ampere (Pica type) fuse protects the battery against high currents due to external shorting. Diode protection against cell reversal is not used in this application, since battery voltage from the two cells is not sufficient to drive one cell into reversal. The battery conforms to the requirements of reference 1.

In order to determine the effects of possible shorting or external heating which would create undesirable hazards, an experimental program in a closed enviornment, was requested by NAVELEX and conducted at NAVSWC/WO in these two areas.

1. NAVSEA Instruction 9310.1, 30 March 1979.

Chapter 2

EXPERIMENTAL

The experimental program was conducted as follows:

1. A single "D" size cell (Mallory LO26S, manufactured November 1977) was heated inside a pressure vessel at a rate of 30°C per minute to a temperature of 600°C.

2. A single PRC battery with heat shrink tubing (manufactured by Mallory in December 1978) was heated inside a pressure vessel at a rate of 20°C per minute to a temperature of 600°C.

3. A modified PRC transmitter with a battery comprised of two unfused "D" size cells, (Mallory LO26S cells manufactured in November 1977) was subjected to an external short and then driven into voltage reversal by an external power supply. The transmitter was modified so that the two cell batteries could be shorted externally.

Pressure inside the pressure vessel of known free volume was measured with a Stratham Model 10255 tranducer. Type K thermocouples were used to measure the temperatures on the cell and battery and were located as shown in Figure 1. Pressure vessel surface temperature was also monitored using a type K thermocouple. The temperatures and cell potentials were recorded on magnetic tape at four-second intervals. The data was gathered and analyzed using a data acquisition system composed of a Fluke 2240B data logger and a Tektronics 4051 computer. The pressure was continuously monitored and recorded on magnetic tape.

Gas samples from the vented cell and battery were analyzed at the National Bureau of Standards. These analyses were made to determine the types and percentages of gasses released upon cell or battery venting.

Chapter 3

RESULTS AND DISCUSSION

A plot of the data taken on the single Mallory L026S cell manufactured in November 1977 is presented in Figure 2. Venting occurred within seven minutes after heating was initiated. At venting, the temperature at negative end of the cell was approximately 155°C, and the pressure in the pressure vessel rose to 45 psig. Heating was continued until the cell potential reached zero. The temperature of the pressure vessel remained constant at 44°C because of its large mass. The measured pressure (45 psig) and the calculated pressure (50 psig) based on the ideal gas law are in good agreement.

The same experiment described above for a single Mallory L026S cell was carried out on the AN/PRC-96 battery. The results are presented in Figure 3. The major differences between the single cell and battery performance is as expected: the battery vented at a lower negative end temperature (approximately 60°C) after only five minutes of heating. The venting was not as rapid as that of the single cell and lasted for about seven minutes. The measured pressure upon venting rose to 65 psig. A calculation similar to that performed on the single cell indicates that the pressure should have risen to 100 psig. The battery results suggest that prolonged exposure of the battery to temperatures in the vicinity of 60°C could cause a venting.

The composition of the vented gas analyzed by the National Bureau of Standards is presented in Table 1. As expected SO_2 is the predominate species in the gas. HCN was not detected and if present is less than 2%. The major species which could cause a problem for the life support system are SO_2, CO and CH_4.

Both CH_4 and CO were present in quantities less than 8%. This level should pose no problem to the life support system. However, if the battery were to vent in a typical submarine radio room, an SO_2 concentration of approximately 150 ppm would be present. In one minute the air circulation system would reduce this concentration to approximately 5 ppm. During this first critical minute it might be possible for radio room personnel to use Emergency Breathing Apparatus and subsequently clear the area.

The final test of this program was the external shorting of the unfused battery in the AN/PRC-96 transmitter. Initially a one-half ohm external load was placed across the battery to maximize heat generation. The battery voltage dropped and remained constant at 3.5 volts. The current remained steady at 7 ampers. After three minutes no venting occurred. The half-ohm load was then replaced by a dead short (resistance of short <0.01 ohm). A current of 12 ampers at a voltage of 1.8 volts was observed. These conditions remained constant for nineteen minutes and again no venting occurred. A possible explanation for the lack of venting upon shorting is that the mass of the transmitter surrounding the battery could remove the generated heat fast enough to prevent venting. In order to cause venting the battery was subjected to a two ampere constant current discharge and driven into reverse. After one hour the battery went into reverse and then vented after two hours. A photograph of the transmitter after battery venting occurred is shown in Figure 4. The gas generated by the battery ruptured the upper gasket and burned a hole in the negative cap. No evidence of fragmentation was observed. It should be emphasized that in order to cause venting the battery had to be driven into reverse.

Chapter 4

CONCLUSIONS

The AN/PRC 96 power supply using two "D" size $LiSO_2$ cells (Mallory L026S) will vent under the application of external heat or when driven into reverse. The venting generates approximately seventeen liters of SO_2 gas at standard temperature and pressure. The transmitter case is unable to contain the vented gasses.

Chapter 5

RECOMMENDATIONS

First and foremost careful consideration should be given to removing all lithium batteries from submarines. This recommendation is based upon the fact that storage data on lithium batteries is limited with respect to performance and safety. If the above can not be complied with the following recommendations should be implemented for the AN/PRC-96 radio transmitter.

1. Containerization of AN/PRC-96 transmitter.

2. Isolation of AN/PRC-96 transmitter.

3. Periodic battery maintenance.

In order to insure the safety of personnel aboard a submarine it would be necessary to design a container capable of containing the vented gases under worst case conditions. If a container the size of a 20 mm ammunition can (volume 850 in^3) were used it would have to withstand an internal pressure of approximately 20 psig. A standard 20 mm can will hold to an internal pressure of 3.5 psig and therefore would not be suitable. If the design of such a container is not feasible we recommend that the following procedures be implemented.

Store the AN/PRC-96 in a cool room ($T<90°F$) capable of being sealed off from the rest of the submarine. In addition, the air in the room should be capable of being completely exhausted.

Check the open circuit voltage of the batteries every six months and if less than 5.7 volts dispose and replace with fresh batteries.

Routinely replace the AN/PRC-96 battery and spares every year with fresh batteries which were manufactured not more than one year prior to installation.

TABLE I. COMPOSITION OF GASSES FROM VENTED MALLORY L026S CELLS AND AN/PRC-96 BATTERY

GAS	L026S CELL (% by volume)	AN/PRC-96 BATTERY (% by volume)
N_2	24.9	21.0
O_2	1.7	0.2
Ar	0.5	0.4
CO_2	6.2	4.6
H_2	3.5	3.9
CH_4	3.2	2.7
CO	1.2	0.6
SO_2	54.5	60.1
unknown*	4.3	6.5

*HCN less than 2%

ACKNOWLEDGEMENT

The authors wish to thank W. Dorko of the National Bureau of Standards, Gaithersburg for performing the gas analysis and T. Peacock of NAVSWC, White Oak for measuring the pressure of the vented gasses.

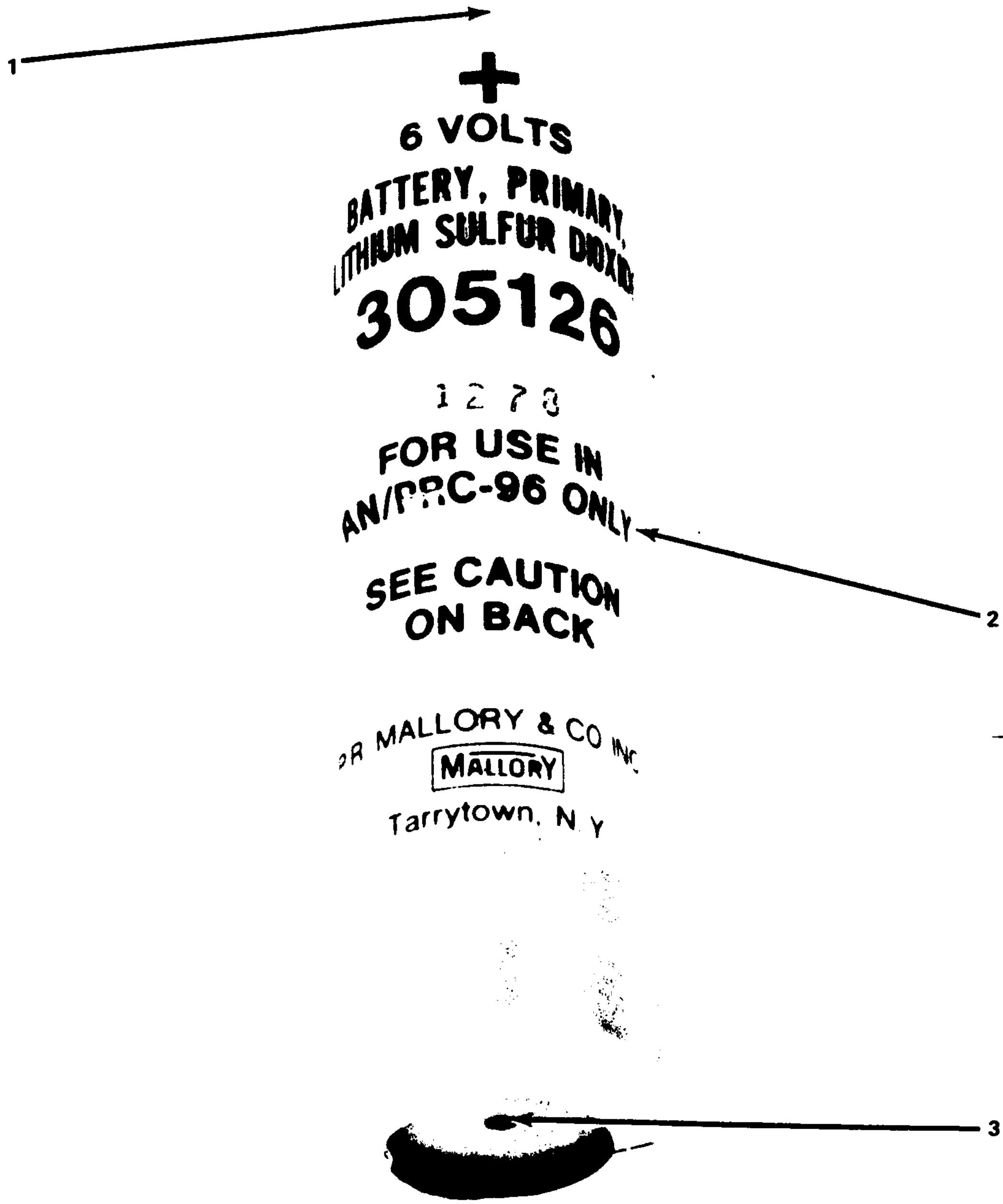

FIGURE 1 SCHEMATIC OF BATTERY SHOWING THERMOCOUPLE LOCATION.

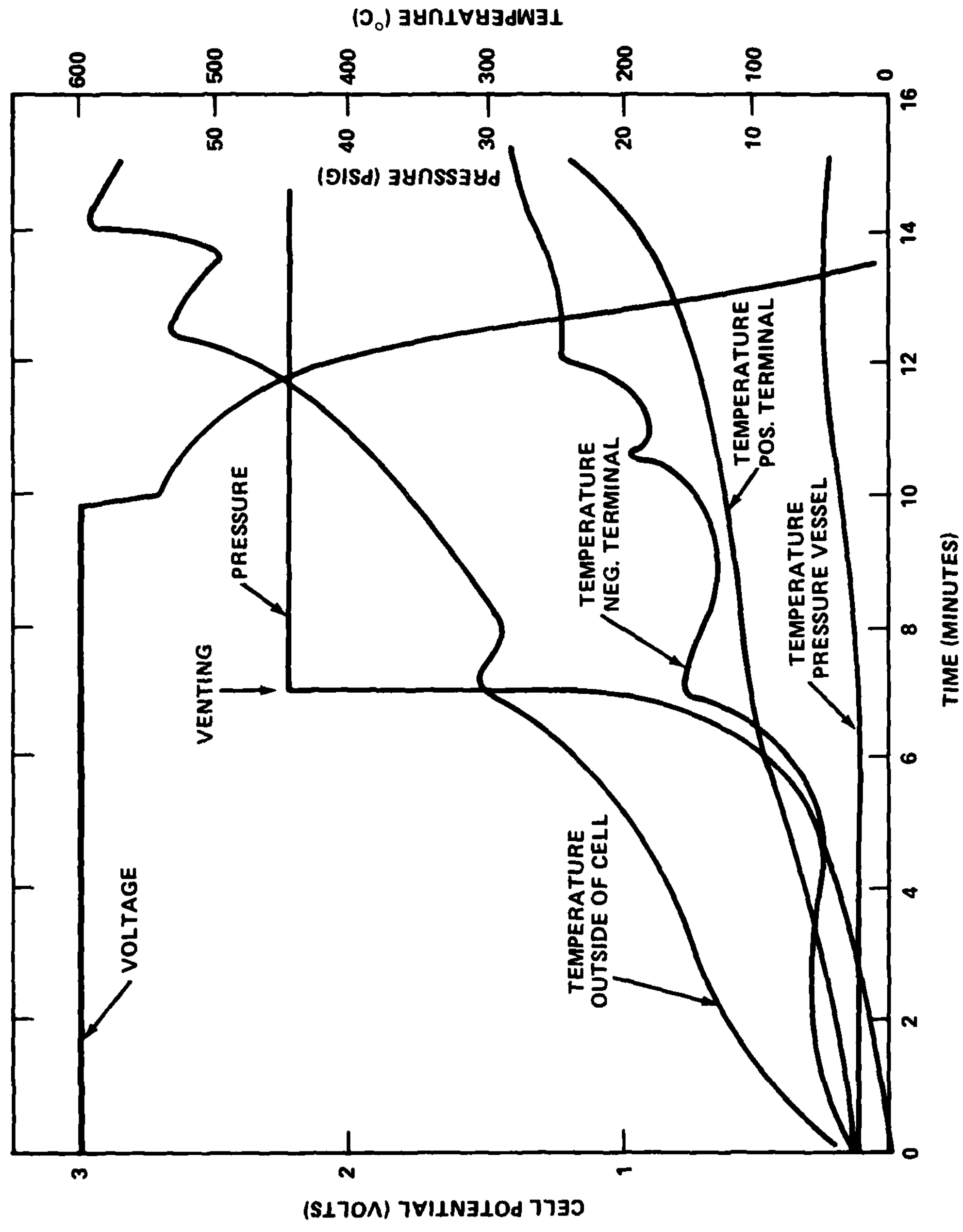

FIGURE 2 EXTERNAL HEATING OF A SINGLE MALLORY L026S CELL VERSUS TIME. CELL POTENTIAL AND VESSEL PRESSURE ARE ALSO INCLUDED.

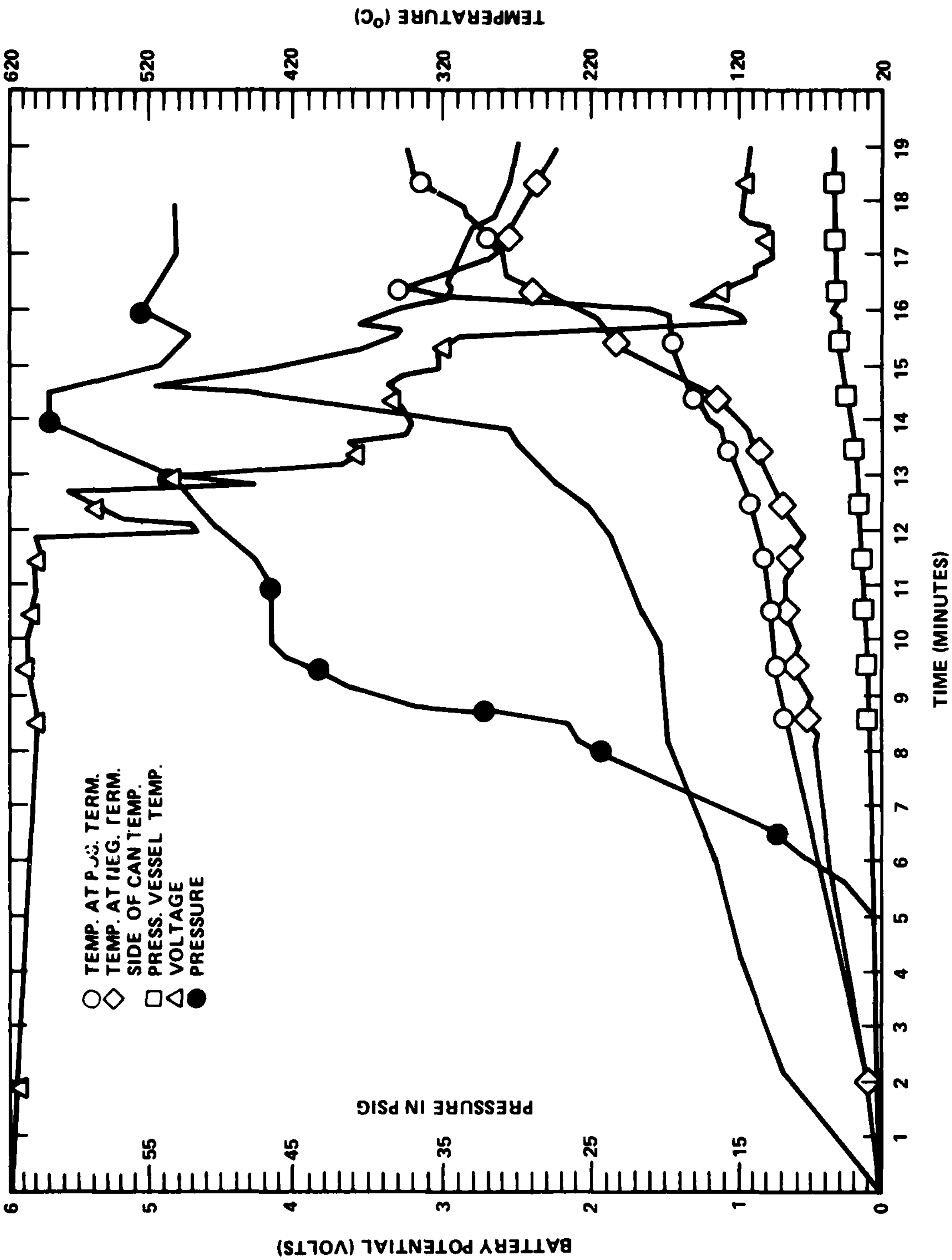

FIGURE 3 EXTERNAL HEATING OF AN/PRC-96 BATTERY VERSUS TIME. CELL POTENTIAL AND VESSEL PRESSURE ARE ALSO INCLUDED.

FIGURE 4 PHOTOGRAPH OF AN/PRC-96 TRANSMITTER AFTER TEST COMPLETION AND BATTERY VENTING.

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